Breeding for Resistance to Sorghum Shoot Fly in Uganda

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SUMMARY

The sorghum varieties Ramatera and Serena which show good recovery resistance to sorghum shoot fly in Uganda have been used successfully as parents to develop resistant lines. Recurrent selection against shoot fly attack using random-mating sorghum populations shows promise.

Sorghum shoot fly Atherigona varia (meigen), occurs throughout the sorghum growing area of East Africa attacking seedlings and young plants, but seldom damaging plants which are over 50 cm. tall, though tillers may be attacked throughout the growing season. It can be responsible for much crop loss, especially in late planted material, or in areas where the dry season is not prolonged. A severe dry season greatly reduces the numbers of this pest, so that sorghum planted at the beginning of the rains generally escapes damage. Later plantings, however, may be seriously affected. Some of our trials in the Machakos district of Kenya, at Makueni have illustrated the importance of the dry season. Normally at Makueni there are two short rainy seasons in which sorghum is grown, separated by a rainless dry season. In one year, a series of heavy showers fell in the dry season between the two rainy periods, and the second sorghum crop was absolutely devastated by shoot fly. During the remaining eight years of trials, it was unusual to have any numbers of shoot fly damaged plants recorded at Makueni at all. A second factor to bear in mind in Uganda is that the selection work for resistance to shoot fly is being done at Serere under conditions where moisture stress is seldom serious. Insect damage in sorghums appears to be much more pronounced when the plant is under any kind of stress, and at Serere, the plants probably recover from shoot fly damage a little more readily than would be the case if they were [illegible] grown under conditions of frequent water shortage.

Types of resistance

Two types of resistance have been distinguished:-

(1) Primary resistance. In this type of resistance relatively few plants are attacked by the fly, and it has been suggested by Ponnaiya (1951) that this may be due to silica deposits in the leaves.

(2) Recovery resistance. This form of resistance is really a tolerance, the initial main shoot is attacked, - indeed, the variety may be very susceptible to the attack of the initial main shoot by the fly, - but the plant responds by producing several synchronous tillers, many of which grow away from the shoot fly attack and produce heads. Evidently it is unrealistic to allow an indefinite length of time for the plants to recover from attack, and at Serere it is generally taken that a resistant plant must produce its crop within a fortnight of the cropping date of the undamaged shoots. In very short rainy seasons, this delay of a fortnight may itself be sufficient to prevent a good yield being harvested. It should be noted that the synchronous tillers of resistant varieties are few, but most head. Susceptible varieties may produce numerous tillers after a shoot-fly attack, but no profitable heads are obtained from them.

The existence of resistance to shoot fly was first noticed about 1961, when a series of sorghum varieties from Serere was grown on the Makerere University Farm. The local Ugandan variety Namatera was also growing on the farm. This variety can be continuously ratooned, provided that fertiliser is applied and the plot is kept weeded, and good grain yields of some 1,800 - 2,200 kg/ha have been recorded from six successive ratoon crops at Makerere. The varieties from Serere under test were very seriously damaged by shoot fly, and looked thoroughly unhappy as a result, whereas the Namatera grew with very little trouble. It was later noticed that the main shoot of Namatera plants was frequently damaged, but tillers then grew up and gave a good harvest. D. Jowett learned from the local people that they considered this variety would not yield properly unless it had been damaged by shoot fly.

The variety Hamatera is a beer sorghum, and is tall, rather late maturing, with very small grains which often have the glumes attached to the seed after threshing.

Breeding for resistance. Hamatera is no use as a grain variety, but was used as a parent in the breeding programme. Hamatera was crossed with male-sterile CK 60A, and the F_1 was then back-crossed again to CK 60A. In the segregating generation from this backcross, plants were selected which showed the characteristic of producing three or four synchronous tillers after damage to the main shoot, and these were used as parents to cross to a range of Serere sorghum varieties which were being developed for grain yield. Selection in the segregating generations from these crosses was also based on observed tillering performance, but it soon became necessary to attempt to screen under high levels of shoot fly infestation, to ensure that it was really shoot fly resistance which was under selection. The variety CK 60 was observed to be very susceptible to the fly, and variety trials were grown out using borders of CK 60 which were planted about ten days to a fortnight before the main trials. The trial design used was the balanced lattice square with small plots, in an attempt to get a reasonable estimate of the amount of shoot fly damage on individual entries. Two successive seasons of selection were done in this way, with two balanced lattice square trials grown in each season. The percentage of infestation in these trials varied from 26 per cent to 55 per cent, so evidently there were very many escapes, and no satisfactory level of selection pressure was being applied.

Ensuring infestation by shoot fly

At this stage, our unit was joined by professional staff from the United States Agricultural Research Service, under a U.S.A.I.D. agreement. Dr. K.J. Starks began to study the problem of breeding for shoot fly resistance. He soon developed a system which rapidly built up large numbers of shoot fly within a given area. Details will be found in Starks (1970), but basically, the method relies on the fact that these flies are attracted to compounds

of ammonia, and fish meal was found to be an attractive bait. The meal was prepared and spread between the rows of the varieties under test, but later meat meal which was available from local manufacturers was used as a substitute, although it was somewhat less effective. A shoot fly susceptible variety such as CK 60 was planted as a border and in between the blocks of the trial about a fortnight before the entries under test were sown. The shoot fly built up on this susceptible edging, and as soon as the varieties under test had reached a susceptible stage, fish meal or meat meal was spread between the rows and the flies were attracted in. Counts indicated that the screening trials were now being done with shoot fly infestation levels of over 90 per cent. This represented an important step forward in the effectiveness of the screening systems, and it was very soon possible to discard a lot of the susceptible material which was being carried along. Results of some of these screening trials are summarised in Table 2, while details of the parent materials are shown in Table 1 (Doggett et al, 1970). It will be seen that good levels of resistance were obtained from some of the original segregates of the backcross of CK 60 by Namatera, and that good material was also obtained from crosses between these segregates and Serena or CB 79. Screening soon showed that Serena itself had a good level of recovery resistance to shoot fly, which was presumably because it was developed under conditions where shoot fly attack was very common. A glance back at the regional variety trial head counts for a number of years showed that Serena nearly always had a higher head number than other varieties, indicating that rather more tillers were produced, and doubtless this was often an effect of recovery from shoot fly attack. Many of the best entries in our variety trials were derived from Serena or from Namatera crosses, and some estimates of these in a yield trial are shown in Table 3 (Doggett et al, 1970). We need more factual information on the extent to which this recovery resistance is responsible for maintaining yield, but certainly Serena is the best yielding variety throughout our trials and has a better yield stability than other entrants. A part of this stability may well be due to its resistance to shoot fly (Majisu and Doggett, in lit.).

Another fact of interest brought out by Starks work was the observation that shoot fly could cause a lot of seedling deaths in susceptible varieties, with no tillering occurring before death.

The breeding programme

Selection and screening of the material from the Serena and Namatera crosses has continued at Serere, this aspect of the work having been taken over by U.S.D.A. A.R.S. entomologists, K. Starks having been followed by L. Barry. Resistance levels as good as or better than that of Serena are showing up in some lines, and yields appear to be every bit as good. Regional yield testing is being done, and any superior material will be released to the farmers (Barry, 1971). Recovery resistance is an important factor in maintaining stable and high yield level of sorghum grain in Uganda.

Primary resistance

Sorghum varieties showing primary resistance reported from Israel by Blum (1965, 1967) and from India by Pradhan and his colleagues (1966, 1971) have been tried under Uganda conditions. In some seasons there have been definite indications that differences in shoot fly infestation due to primary resistance do occur under Uganda conditions, just as they do in Israel and in India. However, when the level of shoot fly incidence is very high indeed, the differences between these varieties in primary resistance tends to become rather narrow. It is clear that under conditions where the rains are of short duration, such primary resistance may be the only effective form, since there may not be time for the recovery resistance to operate properly before soil moisture dries out. A number of these varieties selected in India and Israel for their primary resistance to shoot fly have shown good recovery resistance under Uganda conditions, and are being studied further (Barry, 1970).

Recurrent selection for shoot-fly resistance

In addition to the screening and selection of lines in a fairly conventional manner, a recurrent selection programme has been established at Serere. Doggett's initial sorghum populations included both Serena and Namatera crosses in their composition, and a good many other sorghum varieties

which may have some shoot-fly resistance also went into their make-up (Doggett 1971). These have been subjected to recurrent mass selection by J. Berry, using alternating generations of selfed plant and female choice mass selection, under very high levels of shoot fly attack. After three generations of selection (two selfed plant and one female choice) Berry (1971) reported that differences are quite evident and he hopes that it will be possible to extract lines from these populations after two to four further generations of such mass selection. In making the selections, yield and length of maturity were taken into consideration as well as recovery from shoot fly attack, and in this way it should be possible to favour some primary resistance as well as recovery resistance, which should augment one another in developing satisfactory levels of performance in the presence of high infestations of this pest. Doggett et al (1970) reported high heritability for recovery resistance, as well as a high genetic correlation between recovered plants and yield. Starks et al (1970) found that the genetic variance associated with recovery resistance was largely additive. The system of recurrent selection being practised at Serere should therefore be effective, and does appear to be a practicable method of enhancing resistance to shoot fly, at the same time as increasing yield.

Table 1. Parentage of the sorghum lines screened and selected for resistance to sorghum shoot fly.

Entry	Origin or parentage
Hamatera	A Buganda (Lake Victoria area) Uganda beer sorghum.
'Dobbe'	A Northern Kenya cultivar, presumably selected locally.
'L 29'	A cultivar from Lango, Uganda.
Serena, 'SB 65', 'SB 77'	Strains selected from a cross between 'P.127', a dwarf Kaffir from Swaziland, and Dobbe.
'SUK 1'	A white grain selection from a cross between the Congo regional type 27 U.T., and 'Wira', an indigenous Tanzanian sorghum.
'Combine Type 2'	A Serena selection from natural crosses in Caprock.
Combine Kafir 60 (CK 60), 'Caprock'	Developed in Texas, U.S.A.
'Redlan'	Developed in California, U.S.A.
'CSH-1'	Hybrid sorghum developed in India.
CSP 62 to 79	$(CK\ 60)^2$ x Hamatera
CSP 104 to 157	Serena x CK^2N
CSP 158 to 168	SB 77 x CK^2N
CSP 169 to 195	SB 79 x CK^2N
11 x 60	CK 60 x SB 77
32X 57	$Serena^2$ x CK 60
47X 34	$SUK\ 1^2$ x CK 60
51X 18	SB 65 x CK^2N
52X 36	SB 77 x (CK 60 x Serena)
53X 50	$SB\ 79^2$ x CK 60
52X 61 and 53X 63	SB 79 x CK^2N
51X 73 and 51X 76	SUK 1 x CK^2N
51X 87	CK 60 x CK^2N
51X 142	Serena x (SB 79 x CK^2N)
51X 162	$Dobbe^2$ x (CK 60 x SB 79)

Table 2. Percentage of plant showing recovery resistance in screening trials.

CSF no.	Trials*									
	A	B	C	D	E	F	G	H	I	J
63/1**	83	74	-	-	-	-	80	-	-	67
63/2**	79	87	-	-	-	80	-	-	-	65
63/3**	77	91	-	-	80	84	85	80	93	83
68/3**	86	86	-	-	-	-	-	82	81	83
68/9**	86	71	-	-	-	90	-	-	-	72
73/1**	71	95	-	-	81	-	89	83	79	81
73/2**	87	80	-	-	78	80	85	87	-	77
123**	-	-	82	78	89	-	94	78	78	71
128**	-	-	76	48	-	89	80	-	-	80
131**	-	-	60	73	76	-	89	86	-	76
150**	-	-	74	61	80	79	75	75	-	66
163**	-	-	62	71	-	85	-	-	86	69
174/3**	-	-	60	67	84	80	-	84	-	79
174/6**	-	-	-	55	-	89	-	-	-	74
190*	-	-	76	81	79	84	90	84	-	75
192**	-	-	84	70	-	-	80	-	-	73
194**	-	-	100	86	74	94	85	78	-	79
SB 77	-	-	-	-	-	-	-	-	-	52
SB 79	-	-	-	-	-	-	-	-	-	62
Namatera	72(2)	59	59(2)	64	-	-	-	-	-	72
Serena	74(2)	68(6)	78	79	73(6)	76(6)	77(5)	75(6)	76(5)	76
CK 60	58(2)	47	56(2)	38	25(5)	34(5)	36(6)	43(5)	32(6)	34
LSD 05	16	19	19	21	25	29	22	26	29	12
No. of Rep.	6	6	7	7	2	2	2	2	2	10
% Infes.	26	35	37	55	92	92	92	92	92	91
CV	19	26	28	36	19	20	16	20	23	20

* Numbers in parenthesis are the number of time entries appeared in a replicate if more than once.
** These entries have CK N in their parentage.

Table 3. Grain yields and shoot fly recovery ratings on sorghum varieties - randomized block, 12 replications.

Variety	Shoot fly, % recovered	Heads per 100 plants	Yield in q/ha
Seredo	75.0	106	25.6
Samaterm	72.9	130	18.3
30X 57/1	63.3	132	27.0
5AX 10/2	63.3	141	23.8
5AX 162/1	62.5	175	29.1
5AX 61/2/1	59.2	145	25.5
SB 79	57.5	147	26.0
L 28	57.5	146	24.8
Gebbs	57.5	138	25.8
5AX 142/4	55.8	159	30.2
4AX 34/1/4	51.7	134	22.4
5AX 50/4/1	50.0	124	19.0
5AX 142/9	50.0	121	16.8
5AX 36/1/2	49.5	132	21.3
h x 60/7/2	47.5	88	15.2
5AX 61/6/2	45.8	112	16.8
SB 77	44.2	88	13.6
Combine Type 2	42.5	68	10.9
Redlan	40.8	78	12.3
SUX 1	29.2	97	11.6
CK 60	25.0	51	7.8
Caprock	16.0	37	5.1
LSD .05	9.5	28	5.2
CV, %	23.1	27.0	32.1

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